AGD Landscape & Environment 5 (1) 2011. 11-21.

1:10000 SCALE MAPPING WITH GPS AND FREE GIS TOOLS – COMPARISON WITH TOPOGRAPHIC MAP

ANDOR RÁBAY

Doctoral School of Earth Sciences, Faculty of Sciences, University of Pécs, H-7624 Pécs, Ifjúság u. 6.
email: andorpp@gamma.ttk.pte.hu

Received 7 February 2011; accepted in revised form 3 June 2011

Abstract
Reliability of the road system illustrated on topographic maps with 1:10000 scale is questionable due to their age, but surveying a territory with area over 100 hectares is expensive with classical geodetic tools, although there is no need of geodetic accuracy in most cases. GPS-based mapping method described in this paper is suitable in these situations. The main concept is to keep the costs of the survey as low as possible, therefore free GIS applications and databases were used with navigation purpose GPS receivers. The accuracy provided by these devices is good enough for those purposes where the accuracy of topographic map with 1:10000 scale is adequate. GPS-based mapping can be done to update the road system of existing map or create own detailed road databases. The result of the work is not just a database but a navigation capable digital map, which can aid further activities on the field, like geographic researches, environment protection, tourism, fire service etc.

Keywords: GPS, mapping, free GIS tools, topographic map

1. Introduction

Agriculture, forestry, disaster recovery, environment protection, tourism and geographical researches require topical, up to date maps with detailed road system. The Hungarian topographic maps published in the late ’70s and early ‘80s with 1:10000 scale do not measure up to these expectations in many cases, but there are no newer versions available from Institute of Geodesy, Cartography and Remote Sensing (FÖMI). Surveying territory with area over 100 hectares with classical geodetic tools would be expensive and long-drawn, although there is no need of geodetic accuracy in most cases. Usability of orthophotos depends on land cover, mapping woodlands’ road system is nearly impossible this way.

Modern navigation purpose GPS receivers, free GIS software and public databases give the opportunity to create map that satisfies the requirements originated from the technicalities, with limited budget within a short time. Many scientific researches use GPS but only to navigate with topographic and cadastral maps (Galambos et al. 2009; Macioch, 2006) or map objects that cannot be found on topographic maps (Aporta, 2003; Shrestha, 2006). GPS-based tracking (Williams et al. 2010; Biro et al. 2002; Clark et al. 2006; Stockdale et al. 2008) is popular too.

Since the GPS-based mapping is almost independent from land cover and terrain, it is suitable for updating existing maps and databases or create new detailed maps with reliable content.

To illustrate the benefits of the GPS-based mapping method I have done a survey on a territory where usability of existing sources is questionable. I compared the results with digitized topographic maps and orthophotos. The aim of the paper is to introduce this inexpensive and relatively fast method of mapping road system with GPS and free GIS tools.

2. Methods

2.1. Sample area

The sample area was the South Jakab-hegy (part of the Mecsek) with area of 700 hectares (Fig. 1). The territory contains built-up areas and forest, mainly oak and beech (Fig. 2). The Jakab-hegy has important role in tourism and forestry, and several geological researches took place here, for instance many roads were created to connect the prospect holes of the uranium mining with the existing roads.
The elevation is between 210m and 590m, while the slope varies between 0° and 35°.

Fig. 1. The location of the surveyed area

Fig. 2. Landscape from Zsongor-kő (540 m)

2.2. The theoretical benefits of the method

The most important feature of the GPS-based mapping is that the surveyor has to pass through every roads personally, so it is possible to take notes about the road conditions and find roads that had not been mapped before. This method inhibits the inheritance of false or outdated information from previous maps. The survey has two major theses:

- The boundaries of the surveyed area have to be roads, since only the road system is mapped.
- An existing road is accessible from a road surveyed before. This recursive definition means only that road will be shown on the map that has at least one connection point to an other road (Siegler, 2008).

The two theses guarantee that all and only the passable roads will be mapped within the surveyed area.

2.3. Hardware and software

The accuracy and reliability of both the navigation purpose and mapping grade GPS devices have improved a lot in the last few years (Takács 2002; Wing and Eklund, 2007). To illustrate the capabilities of navigation purpose GPS receivers I used two devices with price under 40 EUR:

- Royaltek RBT-1100 (SiRF Star II xTrac chipset)
- Xaiox Marathon (Nemerix chipset)

These receivers was connected via Bluetooth to a Windows Mobile based HTC Wizard smartphone. The HTC was used to log GPS data and acted as a navigation device.

The main idea of the method is to keep the costs of the survey as low as possible. Free programs satisfy this concept since there is no need for buying software for occasional works. The following applications were used during the mapping and the analysis:

- Russa 1.1.28.15 – freeware tracklogger and map viewer for Garmin and Russa map formats
- GPSBabel 1.4.2 – freeware, open source tracklog and waypoint converter
- MapEdit++ 1.0.61.342 – freeware, open source map editor for Garmin and Russa map formats
- Quantum GIS 1.6.0 – freeware, open source vector and raster based GIS software

2.4. Road classification

The topographic maps with 1:10000 scale have no information about passability of the unpaved roads, but it is an important parameter for applications where transport routes calculated based on these maps, for instance forestry, fire service and tourism. So the main concept was not just surveying the road system but collect data about passability. Four classes were defined:

- Easy to pass – these roads are in daily use and unhampered, so every four-wheel drive vehicle can pass through them
- Hard to pass – special off-road vehicles needed to pass through, since these roads are not in daily use or the rugged surface, stones, vegetation, and ditches hamper the traffic
- Cannot pass – mainly roads that have not been in use for a while, overgrown by bushes and small trees.
- Walkway and trail – only for pedestrian use, mainly marked hiking trails with tourism significance.

2.5. The survey process

The first step (Fig. 3) is to track the border roads mentioned above, take notes about passability and record coordinates of road junctions. After the field work it is recommended to load the tracks and waypoints into the mapping software (MapEdit++) and create the first version of the work map. It is not the final map but will be helpful for the further tracking because it contains the roads have surveyed yet and the waypoints about the road junctions where the tracking should be continued. Since every contributor of the project has GPS device with

navigation capabilities, the logistics can be done through the working map uploaded to the devices. To reduce the overall time and length have to take, it is possible to organise the survey with graph traversal algorithms, but consider that the redundant information originated from the duplicated survey of a road can increase the accuracy through averaging. After each day a new and extended version of working map can be drawn and uploaded to the devices.
MapEdit++ was chosen because it can export directly to Garmin map format, which is suitable for the prevalent GPS mobile platforms (Garmin handheld devices, Android, Symbian, Windows Mobile), therefore miscellaneous devices can be used for the same survey. The maps can be exported to the industry standard ESRI shapefiles, so further GIS processing is possible.

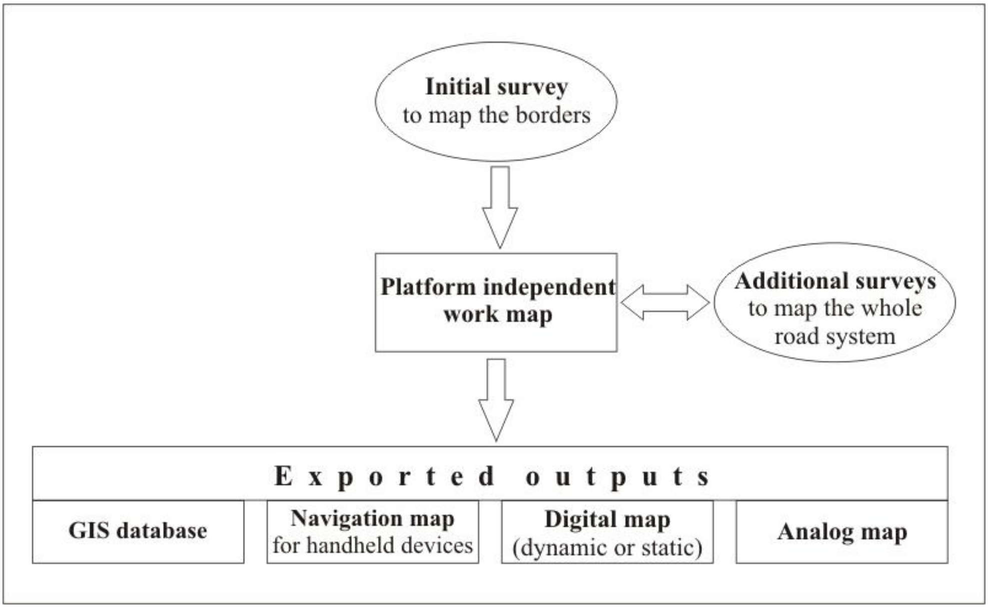

Fig. 3. Flowchart of the survey

2.6. Using free GIS databases

There are more and more free GIS databases available, two of them are frequently used in geographical researches and GPS-based mapping. The SRTM digital elevation model with resolution of 90 m is a good source to create contour map, although its vertical accuracy depends on the land cover and exposure (Szabó and Szabó, 2010; Kugler et al. 2004) due to the radar-based survey. The vector contour map with 10m interval was created with Quantum GIS from the raster SRTM data.
The free CORINE Land Cover (CLC) database is widely used to create the polygon objects for GPS-based maps. CLC2006 version was used after reclassification.

2.7. Comparison with other other sources

To compare the results with the existing sources I have digitized the road system of the surveyed area from the 1:10000 scale topographic map created in 1982 and orthophoto with 1m/px resolution created in 2005. Georeferencing, digitalization and analysis was done with Quantum GIS. Only the fraction of the roads are visible on the orthophoto where the surface is covered by forest, it gives useful information only about the built-up areas, so no further analysis was done with this source.

The accuracy of the 1:10000 scale topographic map is around 5 meters. The same or better accuracy required from the GPS devices, so the results of the survey can be usable to compare and update the content of the topographic map. I have done measurements at four geodetic points in various terrain and weather conditions to determine the accuracy and analize the environment dependence of the navigation purpose GPS receivers. Every measurement contains at least 1200 discrete points.

3. Results and discussion

3.1. GPS accuracy

The measurements proved that modern navigation purpose GPS receivers are able to permanently provide the required accuracy for 1:10000 scale mapping (Table 1). Due to their high sensitivity and advanced processing software these devices are not strongly affected by the terrain or multipath wave propagation. In case of constantly bad receiving conditions (terrain, vegetation) the accuracy can be improved with GPS planning software to determine those periods when the most GPS satellites can be tracked from the selected location (Ransom et al. 2010).

Table 1. GPS accuracy measured at geodetic points

Terrain and environment	Within 5 m (%)	Within 3 m (%)
Built-up area, heavy rain	100	75.4
Hilltop, optimal receiving conditions	100	92.3
Valley, sparse vegetation	100	85.4
Valley, dense vegatation	100	34.3

3.2. Comparison with topographic map

I have completed the survey of the road system within 5 days, without vehicle and contributors. The overall length of the surveyed roads is 63.8 km (Table 2).

Table 2. Compare the length of road classes on GPS-based map and digitized topographic map

Road class	Length on GPS-based map (km)	Length on digitized topographic map (km)
Collector road	9.3	9.3
Residential street	8.4	4.2
Unpaved road (easy to pass)	27.8	
Unpaved road (hard to pass)	3.1	22.8
Unpaved road (cannot pass)	1.4	
Walkway and trail	13.8	8.8
TOTAL	63.8	45.1

The most conspicuous difference is the overall length of the road system on the GPS based map and the digitized map: 29.3% of the existing roads cannot be found on the nearly 30-year-old topographic map. 90.7% of the "missing" roads are located outside the built-up areas, so there is no unambiguous relationship between the longer road system and the growth of Kővágószőlős and Cserkút.

Another interesting question is the correctness of the information can be found on the topographic map compared to the GPS-based map. I have ordered the cases into 3 classes (Table 3).

Table 3. Correctness of information on the topographic map

Case	Length on digitized topographic map (km)	Percentage of total length (%)
Road exists on both maps, with correct road type	31.4	69.6
Road exists on both map, with incorrect road type	8.3	18.4
Road exists only on topographic map	5.4	12

The fact that roads are illustrated with incorrect road types can be originated from the age of the map, since several unpaved road have been paved and walkways have been extended to unpaved road (Table 4), but it is astounding that 12% of the roads from the topographic map cannot be found on the field. 100% of them are unpaved roads, walkways and trails.

Table 4. Incorrect road types on topographic map

Case	Inside the built-up area (%)	Outside the built-up area (%)
Unpaved road instead of collector road	0	4.0
Unpaved road instead of residential street	37.6	0
Walkway/trail instead of unpaved road	0	58.4

4. Conclusion

As the survey pointed out, reliability of the content of topographic map is questionable due to its age, while the usage of orthophoto is limited by the land cover. The main benefits of the GPS-based mapping method are the cost-effectiveness and the integrity of the database: all and only the existing roads will be mapped and illustrated with the correct road type while the free GIS applications and databases help to reduce the overall cost of the survey. Using free software is especially recommended for those who do not have to do regular mapping works.

The method based on universal mobile map format, therefore most of the smartphones and navigation purpose GPS devices suitable for mapping. This conception help to keep hardware costs low, while the accuracy provided by the devices is good enough for those purposes where the accuracy of topographic map with 1:10000 scale is adequate. The result of the work (Fig. 4) is not just a database but a navigation capable digital map, which can help tracking changes (environment protection) and aid further activities on the field, like tourism, geographic researches, disaster recovery, agriculture etc. Attaching data collected with other sensors to GPS measurements can help to develop complex GIS databases (Pázmányi et al. 2004).

The GPS-based mapping method is suitable for larger areas up to 30-50 km^2 by splitting up the territory to smaller parts. The time required by the survey can be reduced by increasing the number of the contributors. GPS-based mapping is also beneficial in education of geoinformatics, since the students can acquire the principles of GPS measurements, mapping, and learn to use GIS applications and geodatabases.

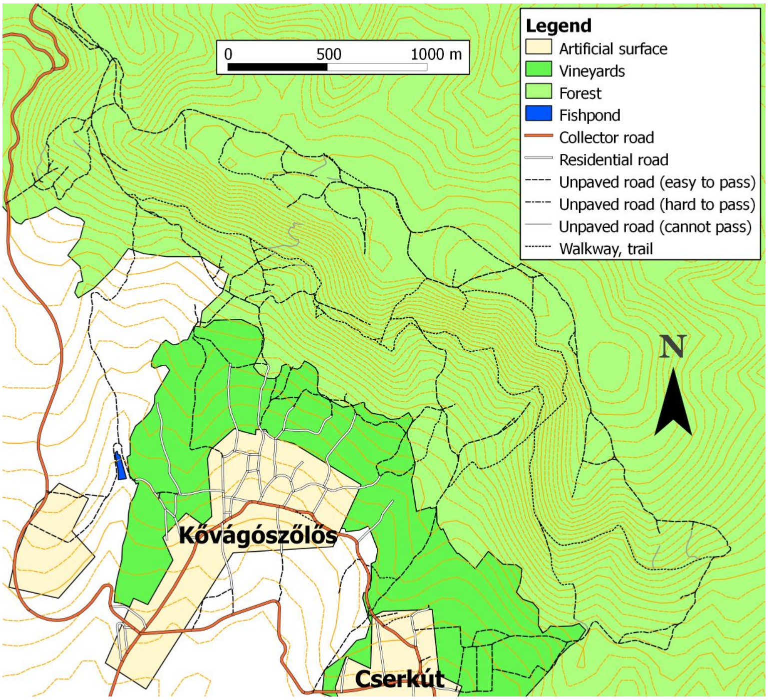

Fig. 4. The map created with GPS-based method

References

Aporta, C. (2003): New Ways of Mapping: Using GPS Mapping Software to Plot Place Names and Trails in Igloolik (Nunavut). *Arctic* **56** (4): 321-327.

Biro, D. – Guilford, T. – Dell'Omo, G. – Lipp, H.-P. (2002): How the viewing of familiar landscapes prior to release allows pigeons to home faster: evidence from GPS tracking. *The Journal of Experimental Biology* **214**: 3833-3844

Clark, P.E. – Johnson, D.E. – Kniep, M.A. – Jermann, P. – Huftash, B. – Wood, A. – Johnson, M. – McGillivan, C. – Titus, K. (2006): An Advanced, Low-Cost, GPS-Based Animal Tracking System. *Rangeland Ecology & Management* **59** (3): 334-340.

Galambos, Cs. – Timár, G. – Székely, B. (2009): GPS navigation on historical and modern geological maps. *Földtani Közlöny* **139** (1): 93-99. (in Hungarian)

Kugler, Zs. – Ládai, A.D. – Barsi, Á. (2004): Comparison of digital terrain models in urban area. *Geodézia és Kartográfia* **56** (4): 10-15. (in Hungarian)

Macioch, A. (2006): Modern methods of use of geographic maps in field research for localisation of objects. *Miscellanea Geographica* **12** (1): 297-304.

Pázmányi, S. – *Dobos,* A. – Pajna, S. (2004): The accuracy and applicability of GPS-based localization in agriculture. *Acta Agraria Debreceniensis* **13**: 157-160. (in Hungarian)

Ransom, M.D. – Rhynold, J. – Bettinger, P. (2010): Performance of Mapping-Grade GPS Receivers in *Southern* Forest Conditions. *RURALS: Review of Undergraduate Research in Agricultural and Life Sciences* **5** (1): 1-12.

Shrestha, H.L. (2006): Using Global Positioning System (GPS) and Geographic Information Systems (GIS) in Participatory Mapping of Community Forest in Nepal. *The Electronic Journal on Information Systems in Developing Countries* **25** (5): 1-11.

Siegler, Á. (2008): Unique characteristics of map databases in navigation. *Geodézia és Kartográfia* **60** (10): 16-19. (in Hungarian)
Stockdale, R.J. – McLelland, S.J. – Middleton, R. – Coulthard, T.J. (2008). Measuring river velocities using GPS River Flow Tracers (GRiFTers). *Earth Surface Processes and Landforms* **33** (8): 1315-1322.
Szabó, G. – Szabó, Sz. (2010): Checking the accuracy of the database collected during a Shuttle Radar Topography Mission (SRTM) in Hungarian sample areas. *Geodézia és Kartográfia* **62** (3): 31-35. (in Hungarian)
Takács, B. (2002): Experiences in kinematic GPS measurements. *Geodézia és Kartográfia* **54** (5): 22-25. (in Hungarian)
Williams, B. – Walsh, M. – Gormally, M. – Walls, S. – Sheanan, J. (2010): Resource selection by hill sheep: direct flock observations versus GPS tracking. *Applied Ecology and Environmental Research* **8** (4): 279-300.
Wing, M.G. – Eklund, A. (2007): Performance Comparison of a Low-Cost Mapping Grade Global Positioning Systems (GPS) Receiver and Consumer Grade GPS Receiver under Dense Forest Canopy. *Journal of Forestry* **105** (1): 9-14.